Computer translation of JP 2000-039531
'Optical signal transmission system and its production'

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[0001]
[Field of the Invention]
The lightwave signal transmission system to which this invention makes optical waveguide carry out end-face association of the light from an end-face light emitting device -- setting -- association -- low -- it is related with degree structure which mode-izes and enables reduction of guided wave loss, and the method of manufacturing this simple.

[0002]
[Description of the Prior Art]
These working speeds and accumulation scales improve by the advance of IC technique or LSI technology, and high-performance-izing of microprocessor ** and large capacity-ization of a memory chip are progressing quickly. Under such a situation, a high speed and densification, and electric wiring delay of signal wiring serve as a neck of the above-mentioned high-performance-izing. As a technique which can solve this problem, the optical interconnection (optical wiring) attracts attention. Although it is thought that application to various hierarchies, such as between the chips between the boards between device equipment and in device equipment and in a board, is possible for optical wiring, the lightwave signal transmission system which makes optical waveguide a transmission line at a comparatively short-distance signal transmission is effective like [during a chip], for example.
[0003] Here, when applying optical-wiring which used optical waveguide to the transmission line for multi chip modules (MCM) to which for example, between LSI is connected, the

laser diode (LD) and light emitting diode (LED) of an edge surface-emitting type are conventionally used as a light emitting device of a transmitting side. The example of a configuration of the typical lightwave signal transmission system which used the light emitting device of optical waveguide and an edge surface-emitting type for drawing 9 is shown. In drawing 9 (a), the optical waveguide WG 3 which extends in the field inboard is formed on the substrate 21. This optical waveguide WG 3 surrounds a core 23 by the clad 22 which consists of an ingredient with a refractive index lower than this. Optical waveguide WG 3 has the perpendicular processing side to the substrate 21, and the perpendicular flat side of the core 23 exposed to this processing side is set to core end-face 23a.
[0004] The light emitting device 30 is mounted on the above-mentioned substrate 21. When the above-mentioned light emitting device 30 is laser diode, the longitudinal direction of the barrier layer 31 has agreed in the extension direction of the above-mentioned core 23, and is made as [carry out / the beam spot BS from the end of this barrier layer 31 / to the center section of the core 23 / image formation]. In addition, the light emitting device 30 is correctly mounted here on the clad 22 which had a part of thickness left behind not on right above [of a substrate 21] but on this substrate 21. This is for adjusting the location of the beam spot BS according to the main height of a core 23. The so-called end-face coupling scheme which carries out incidence of the light from the end face of a barrier layer 31 to the direct core 23 as shown in drawing 9 is effective, without making optics, such as a lens for optical convergence, intervene among both, in order to raise the joint effectiveness of a light emitting device 30 and optical waveguide WG 3 and to reduce a noise.

[0005]
[Problem(s) to be Solved by the Invention]
By the way, the light from the light emitting devices 30, such as laser diode, has an certain amount of angle of divergence to the field inboard and the perpendicular direction of a substrate 21,

and since the angles of divergence in these both directions differ mutually, generally the beam-spot BS configuration serves as an ellipse. Here, the above-mentioned optical waveguide WG 3 is the optical waveguide for multimode propagation, and since a means by which incident light is converged on the top where the cross-sectional area of a core 23 is large does not exist when an end-face coupling scheme is adopted, even the large beam periphery section component of an angle of divergence will combine with a core 23, and the so-called higher-mode association will arise. This condition is shown in drawing 9 (b) and drawing 9 (c). The typical plan of the lightwave signal transmission system which showed drawing 9 (b) to drawing 9 (a), and drawing 9 (c) are the typical sectional views which met the center line of optical waveguide WG 3.

[0006] while light repeats reflection at a big include angle in the interface of a core 23 and a clad 22, in order to spread in the higher mode -- low -- compared with degree the mode, the count of reflection per unit travelling distance increases. Consequently, guided wave loss increases and there is a problem that the output of the outgoing radiation light of optical waveguide declines. therefore -- the time of making multimode optical waveguide carry out end-face association of the light from a light emitting device -- as much as possible -- association -- low -- it mode-izes, guided wave loss is suppressed, and degree thing [increasing an output] leads to stable lightwave signal transmission. Then, this invention aims at offering the approach of manufacturing this simple to the lightwave signal transmission system which enables starting stable lightwave signal transmission.

[0007]

[Means for Solving the Problem]

This invention makes the end face of said core section at least the music convex section which serves as a convex toward a light emitting device in the incidence end face of optical waveguide in the lightwave signal transmission system made as [make / introduce the light from a light emitting device to said

core circles by end-face association, and / it / spread]. the lens effectiveness of this music convex section -- the large beam periphery section component of an angle of divergence -- a beam component with a seemingly small angle of divergence -- the same -- the interior of the core section -- low -- it can spread now in degree the mode and the above-mentioned purpose is attained.

[0008] What is necessary is just to etch optical waveguide until it forms the etching mask which has the edge profile projected in the shape of a music convex in the duplication part with the core section in the front face of the clad section of the optical waveguide beforehand formed along with that field inboard on the substrate and the whole cross section of the core section is exposed to it at least through this etching mask in order to form this music convex section.

[0009]

[Embodiment of the Invention]

The lightwave signal transmission system of this invention controls generating of the higher-mode propagation which was the demerit of end-face association by giving the lens effectiveness to a core end face. The music convex section of a core end face is taken as a convex in either [at least] the section profile of the field inboard of a substrate, or a vertical section profile. When it is a convex only in the section profile of field inboard, a funneling effect is acquired only to the component within a field of a beam, and when it is a convex only in a vertical section profile, a funneling effect is acquired only to the vertical component of a beam. When it is a convex in the section profile of both field inboard and a perpendicular direction, a funneling effect is acquired to the beam component which spreads in all the directions. In addition, the music convex section in this invention may be any of the spherical surface and the aspheric surface.

[0010] What is necessary is just to adopt anisotropic etching conditions, in case optical waveguide is etched through the etching mask which has the edge profile projected in the shape

of a music convex in the duplication part with the core section, in order to form the core section from which the section profile of field inboard becomes a convex. Anisotropic etching can be attained by raising the incidence energy of the ion to a workpiece by approaches, such as bias impression, in reactive ion etching which used the plasma. Thereby, the incidence end face formed becomes almost perpendicular to a substrate side, and a clad end face and a core end face are formed as a continuation side.

[0011] On the other hand, in order to form the core section from which a vertical section profile also becomes a convex in addition to field inboard, the end face of the core section is made to project from the incidence end face of said optical waveguide by forming the core section and the clad section using the ingredient with which etch rates differ mutually beforehand, and etching on conditions to which the etch rate of the core section becomes slow compared with the clad section. Such etching can be performed under isotropic etching conditions. Wet etching for which etching conditions generally used the suitable etching reagent for ******, or dry etching which makes radical reaction a subject is realized. In addition, the condition of the edge of the lobe of the core section changes with size of the etch selectivity at this time. When the etch selectivity between the core section and the clad section is not so large, the edge of a lobe becomes to some extent round during this etching. Therefore, if it seems that lens effectiveness sufficient as [this] can be demonstrated and a good optical funneling effect can be expected, especially subsequent processing is unnecessary.

[0012] However, when demonstrating more sufficient lens effectiveness, it is much more suitable to round off a lobe by heat treatment. However, in order to make only the core section transform during heat treatment and to make it not make the clad section deform, the ingredient selection which also took glass transition temperature into consideration in addition to the above-mentioned etching property is important. That is, the lobe of the core section changes to the music convex decided by the

viscosity and surface tension of the ingredient in a softening condition or a melting condition by constituting the core section using an ingredient with a low glass transition temperature compared with the clad section, and heat-treating at the temperature which may be made to transform only the core section. Thereby, a core end face from which the both sides of the section profile of the field inboard of a substrate and a vertical section profile become a convex can be formed.
[0013] Even if it forms which core end face, etching is performed until it exposes the whole cross section of the core section. that is, whether it leaves the clad of the lower part of the core section somewhat on a substrate, or removes all clads and exposes a substrate, it is further -- it is -- it does not matter even if it removes some surface sections of a substrate. Since a light emitting device is mounted in the removal section of optical waveguide in this invention, it is important to set up the etching depth so that the height of the luminescence side of this light emitting device may agree with the core of the core section.
[0014] By the way, that transparency is high and there is little guided wave loss as conditions required of the clad section which constitutes optical waveguide, and the core section, there being little aging of a refractive index or the volume, and excelling [in thermal resistance]-in consideration of solder mounting of luminescence and photo detector ** are mentioned. As an ingredient which fulfills these conditions, polymeric materials, such as ultraviolet-rays hardening resin, such as an epoxy system and acrylic, and polyimide, are known for the inorganic material with the quartz and the organic material. Especially polymeric materials have low cost, and production by the low-temperature process is possible for them, and, moreover, they have the merit that the correspondence to large-area-izing is also easy.

[0015]
[Example]
Hereafter, the concrete example of this invention is explained.
[0016] an example 1 -- here, the example of 1 configuration of

the lightwave signal transmission system which formed the water planoconvex surface part in the incidence end face of optical waveguide is explained, referring to drawing 1 . In drawing 1 , the optical waveguide WG 1 which extends in the field inboard is formed on the substrate 1. This optical waveguide WG 1 surrounds a core 3 by the clad 2 which consists of an ingredient with a refractive index lower than this. Although optical waveguide WG 1 has the perpendicular incidence end face to the substrate 1, the water planoconvex surface part 4 where this incidence end face is not flat, it projects toward the center line of a core 3, and an amount increases is formed.

[0017] On the above-mentioned substrate 1, laser diode is mounted as a light emitting device 10. The longitudinal direction of the barrier layer 11 of a luminous layer 10 has agreed in the extension direction of the above-mentioned core 3, and is made as [carry out / the beam spot BS from the end of this barrier layer 11 / to the center section of the core 3 / image formation]. In addition, the light emitting device 10 is correctly mounted here on the clad 2 which had a part of thickness left behind not on right above [of a substrate 1] but on this substrate 1. This is for adjusting the location of the beam spot BS according to the main height of a core 3.

[0018] In the above-mentioned lightwave signal transmission system, the breadth component of the field inboard (horizontal direction) of a substrate 1 can be completed by this example among the component of the laser beam emitted by existence of the water planoconvex surface part 4 from the above-mentioned light emitting device 10. Drawing 1 (b) and drawing 1 (c) are the typical sectional views which met the center line of the typical plan of the lightwave signal transmission system shown in drawing 1 (a), and optical waveguide WG 1. Although signs that the big beam periphery component of an angle of divergence is changed into parallel light according to the lens effectiveness of the water planoconvex surface part 4, and goes the inside of a core 3 straight on as a case ideal for drawing 1 (b) are shown, even if it does not become parallel light in this way,

compared with the case where a core end face is flat, the incident angle of the laser beam to the interface of a core 3 and a clad 2 can be made small. therefore -- low -- mode [degree] propagation is attained, guided wave loss is suppressed, and the optical output in an outgoing radiation edge can be increased.
[0019] an example 2 -- here, the manufacture process in the case of forming the incidence end face of the optical waveguide of the lightwave signal transmission system shown in drawing 1 shown above by anisotropic etching is explained, referring to drawing 2 thru/or drawing 5 . First, as shown in drawing 2 , on the substrate 1 which consists of ingredients, such as silicon and glass, through the spin coat of polymethylmethacrylate, and heat treatment, the laminating of the core layer with a high refractive index was carried out to this order, then patterning of this core layer was carried out, and the core 3 was formed rather than lower cladding layer 2a and this lower cladding layer 2a. The dry etching through the metal mask which is not illustrated, for example performed this patterning.
[0020] Next, as shown in drawing 3 , all over a base, this up cladding layer 2b that formed up cladding layer 2b evenly through a spin coat and heat treatment consists of the same ingredient as lower cladding layer 2a, and constitutes the clad 2 which has two incomes with this lower cladding layer 2a, and encloses a core 3. Next, as shown in drawing 4 , the etching mask 5 which consists of metallic materials, such as aluminum and Ti, was formed in the top face of the above-mentioned clad 2. Heights 5a projected in the shape of a music convex in the duplication part with a core 3 is formed in the edge of this etching mask 5.
[0021] Next, anisotropic etching of a clad 2 and a core 3 was performed through this etching mask 5 using the oxygen plasma. Consequently, as shown in drawing 5 , the water planoconvex surface part 4 reflected as it was was formed [profile / edge] in the incidence end face of optical waveguide WG 1 in the pattern of the etching mask 5. After this, the etching mask 5 was removed, the light emitting device 10 was mounted in the removal section of optical waveguide according

to the conventional method, and the lightwave signal transmission system as shown in drawing 1 was produced.
[0022] an example 3 -- here, the example of 1 configuration of the lightwave signal transmission system which made the core end face the curved-surface section is explained among the incidence end face of optical waveguide, referring to drawing 6 . In addition, the reference mark of drawing 6 is as common as drawing 1 shown above in part. In drawing 6 , among the incidence end face of optical waveguide WG 2, although it considers as the same water planoconvex surface part 4 as an example 1 about the clad end face, let the core end face be 3s of curved-surface sections. 3s of this curved-surface section is a convex also in a vertical section profile also in a horizontal section profile.
[0023] In the above lightwave signal transmission systems, the component of all the directions of the laser beam emitted by the existence of 3s of curved-surface sections from the above-mentioned light emitting device 10 can be completed. Drawing 6 (b) and drawing 6 (c) are the typical sectional views which met the center line of the typical plan of the lightwave signal transmission system shown in drawing 6 (a), and optical waveguide WG 2. Although signs that the big beam periphery component of an angle of divergence is changed into parallel light according to the lens effectiveness of the water planoconvex surface part 4, and goes the inside of a core 3 straight on as a case ideal for drawing 6 (b) and drawing 6 (c) are shown, even if it does not become parallel light in this way, compared with the case where a core end face is flat, the incident angle of the laser beam to the interface of a core 3 and a clad 2 can be made small. therefore -- low -- mode [degree] propagation is attained, guided wave loss is suppressed, and the optical output in an outgoing radiation edge can be increased.
[0024] an example 4 -- here, the manufacture process in the case of forming the incidence end face of the optical waveguide of the lightwave signal transmission system shown in drawing 6 shown above by isotropic etching and heat treatment is explained, referring to drawing 7 and drawing 8 . First,

formation of lower cladding layer 2a, patterning of a core 3, formation of up cladding layer 2b, and formation of the etching mask 5 were performed like the example 2. However, what has a glass transition temperature lower than a clad 2 was chosen slower [the etch rate in the below-mentioned isotropic etching] as a component of a core 3 than a clad 2.

[0025] Next, the clad 2 and the core 3 were etched according to isotropic etching conditions through the above-mentioned etching mask 5. However, since the etch rate of the core 3 at this time was slow compared with the clad 2, the incidence end face of optical waveguide WG 2 did not become in the water planoconvex surface part 4 which reflected the edge profile of the etching mask 5 as it was extensively, but changed into the condition that only the core end face was left behind as some lobe 3p, as [show / in drawing 7]. Next, the etching mask 5 was removed and it heat-treated at the temperature of under the glass transition temperature of a clad 2 more than the glass transition temperature of a core 3. Thereby, as shown in drawing 8 , lobe 3p changed to 3s of curved-surface sections. The configuration of 3s of this curved-surface section is decided by the viscosity and surface tension of a component of a core 3. After this, the light emitting device 10 was mounted in the removal section of optical waveguide according to the conventional method, and the lightwave signal transmission system as shown in drawing 6 was produced.

[0026] As mentioned above, although this invention was explained based on the example of four examples, this invention is not limited to these examples at all, and modification, selection, and combination are possible for it suitably about details, such as a configuration of a lightwave signal transmission system, and a configuration of optical waveguide, the processing approach.

[0027]
[Effect of the Invention]
Even if it is the case where end-face association of the light from an end-face light emitting device is carried out in the

incidence end face of optical waveguide according to this invention so that clearly also from the above explanation -- the device of the configuration of a core end face -- low -- since it becomes combinable to degree the mode, guided wave loss can be suppressed and a high optical output can be obtained. The lightwave signal transmission system which harnessed the original advantage of end-face association, such as high joint effectiveness and a low noise, in full by this is realized. This invention serves as indirect exchange of the high speed and densification of the signal wiring in various electronic equipment, and the value on the industry is very large.

[Brief Description of the Drawings]
[Drawing 1] It is drawing showing the example of 1 configuration of the lightwave signal transmission system of this invention which formed the water planoconvex surface part in the incidence end face of optical waveguide, and (a) is the typical sectional view where an outline perspective view and (b) met the typical plan, and (c) met in the extension direction of optical waveguide.
[Drawing 2] In the manufacture process of the lightwave signal transmission system of drawing 1 , it is the outline perspective view showing the condition of having carried out patterning of the core on the lower cladding layer.
[Drawing 3] It is the outline perspective view showing the condition of having carried out the laminating of the up cladding layer on the base of drawing 2 .
[Drawing 4] It is the outline perspective view showing the condition of having carried out patterning of the etching mask on the clad of drawing 3 .
[Drawing 5] It is the outline perspective view showing the condition of having carried out patterning of the optical waveguide through the etching mask of drawing 4 , and having formed the water planoconvex surface part in the incidence end face.
[Drawing 6] It is drawing showing other examples of a configuration of the lightwave signal transmission system of this

invention which formed the curved-surface section in the incidence end face of optical waveguide, and (a) is the typical sectional view where an outline perspective view and (b) met the typical plan, and (c) met in the extension direction of optical waveguide.
[Drawing 7] In the manufacture process of the lightwave signal transmission system of drawing 6 , it is the outline perspective view showing the condition of having carried out patterning of the optical waveguide through the etching mask, and having formed the lobe in the end face of a core.
[Drawing 8] It is the outline perspective view showing the condition of having changed the lobe of drawing 7 to the curved-surface section by heat treatment.
[Drawing 9] The incidence end face of optical waveguide is drawing showing the example of 1 configuration of the even conventional lightwave signal transmission system, and (a) is the typical sectional view where an outline perspective view and (b) met the typical plan, and (c) met in the extension direction of optical waveguide.
[Description of Notations]
1 -- Substrate 2 -- Clad 2a -- Lower cladding layer 2b -- Up cladding layer 3 -- Core 3p -- (core) Lobe 3s -- Spherical-surface section 4 -- Water planoconvex surface part 5 -- Etching mask 5a -- (etching mask) Heights 10 -- Light emitting device 11 -- Barrier layer WG1, WG2 -- Optical waveguide BS -- Beam spot

Claims
[Claim 1] The optical waveguide which consists of the core section and the clad section which surrounds this core section, and extends in the field inboard of this substrate on a substrate, It is allotted to the incidence end-face side of said optical waveguide on said substrate, and has the light emitting device which carries out outgoing radiation of the light to the field inboard of this substrate. It is the lightwave signal transmission system made as [make / introduce the light from said light emitting device to said core circles by end-face association, and

/ it / spread]. The lightwave signal transmission system characterized by having the music convex section from which the end face of said core section serves as a convex toward said light emitting device in the incidence end face of said optical waveguide at least.
[Claim 2] Said music convex section is a lightwave signal transmission system according to claim 1 characterized by being a convex in either [at least] the section profile of the field inboard of said substrate, or a vertical section profile.
[Claim 3] The lightwave signal transmission system according to claim 1 characterized by each of said core sections and said clad sections consisting of polymeric materials.
[Claim 4] The 1st process formed so that the optical waveguide which consists of the core section and the clad section which surrounds this core section may be made to extend on a substrate at the field inboard, The 2nd process which forms in the front face of said clad section the etching mask which has the edge profile projected in the shape of a music convex in the duplication part with said core section, The 3rd process which forms a music convex-like incidence end face by etching said optical waveguide through said etching mask until the whole cross section of the core section is exposed at least, The manufacture approach of the lightwave signal transmission system characterized by having the 4th process mounted in the removal section of said optical waveguide so that the light emitting device which carries out outgoing radiation of the light to the field inboard of said substrate may be made to counter said incidence end face.
[Claim 5] The manufacture approach of the lightwave signal transmission system according to claim 4 characterized by forming the core section from which the section profile in the field inboard of said substrate becomes a convex by performing etching in said 3rd process under anisotropic etching conditions.
[Claim 6] The manufacture approach of the lightwave signal transmission system according to claim 4 characterized by making the end face of this core section project from the incidence end face of said optical waveguide by forming said

core section and said clad section using the ingredient with which etch rates differ mutually, and performing etching in said 3rd process under the conditions which make the etch rate of this core section smallness compared with this clad section.
[Claim 7] the manufacture approach of the lightwave signal transmission system according to claim 6 characterize by forming the core section from which a vertical section profile also become a convex to said substrate by heat-treating at the temperature which may be make to transform only this core section , and rounding off the projected end face after forming said core section using an ingredient with low glass transition temperature compared with said clad section and completing etching in said 3rd process .
[Claim 8] The manufacture approach of the lightwave signal transmission system according to claim 4 characterized by forming said optical waveguide using polymeric materials.